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Paralleling Dissimilar Generators: Part 3 – Load Sharing Compatibility

■ White Paper

By Gary Olson, Director of Technical Support

Generator sets cannot operate in a stable fashion in parallel with other sources unless the loading on the generator set is controlled. When generator sets are operating together on an isolated bus (that is, not grid-paralleled), they are commonly provided with equipment to allow each machine to operate at the same percentage of load as the percentage of load on the total system. This is termed a “load sharing control system.” Many options are available for load sharing controls from various manufacturers, and many of these options are not compatible with each other. So, when considering the paralleling of dissimilar generator sets, or adding generator sets to an existing paralleling system, it is critical to understand how load sharing can be accomplished.

Load sharing factors

When a generator set is in a paralleled arrangement, the voltage and frequency outputs of the generator sets are forced to exactly the same values when they are connected to the same bus. Consequently, generator set control systems cannot simply monitor bus voltage and speed as a reference for maintaining equal output levels, as they do when operated in isolation from one another. If, for example, one set operates at a higher excitation level than the other sets, the reactive load will not be shared equally. Similarly, if a generator set is regulated to a different speed than the others, it will not share kW load properly with other generator sets in the system. Each generator set in the system has two active control systems always in operation: the excitation control system regulating voltage, and the fuel control system regulating engine speed. Generators can be sharing kW load and have problems sharing kVAR load, and vice versa. Successful load sharing requires addressing of both kW and kVAR load sharing, under both steady state and transient conditions.

Real power sharing (expressed as kW or unity power factor load) depends on speed control and fuel rate control between the generator sets based on percentage of kW load. Reactive power (expressed as kVAR or zero

power factor load) is primarily dependent upon voltage control and excitation system control that is dependent on the percentage of load between the generator sets.

Although it is sometimes possible to integrate systems from different manufacturers, generator set governors and load sharing controls should be of the same manufacturer and model to avoid conflicts in responsibility for proper system operation. When that is not possible or practical, the detailed options of this paper can be consulted for alternatives. Several types of load sharing control are available:

- Droop governing and voltage regulation (a.k.a. “reactive droop compensation”)
- Isochronous kW load sharing
- Isochronous voltage kVAR load sharing
- Cross current compensation for kVAR load sharing

Droop load sharing controls

As illustrated in Figure 1, droop governing or voltage regulation allows the engine speed (measured in Hz) or alternator voltage to decline by a predetermined percentage of the output range as the load increases. By contrast, if two machines start at the same frequency and voltage at no load, and maintain those values through all load levels (steady state), the system is said to be operating isochronously.

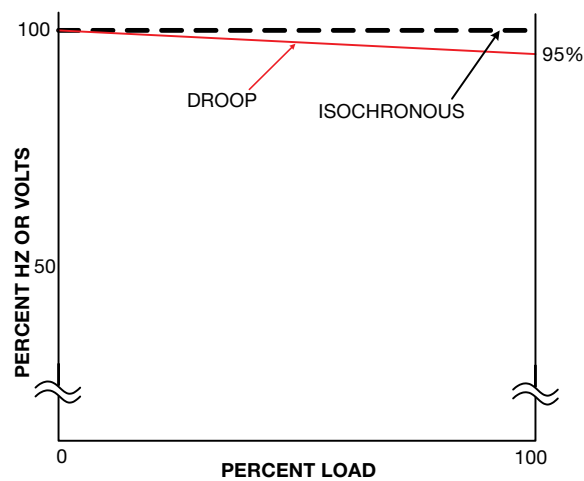


Figure 1 - Droop vs. isochronous load sharing.

For a droop system to function correctly, the following conditions need to exist:

- The generators must have the same no load frequency and voltage when they are disconnected from the bus.

- Each generator must be set to drop voltage at the same rate from no load to full load.
- Each generator must be set to drop frequency at the same rate from no load to full load.

It is worth noting that frequency droop and voltage droop do not need to be the same percentage. Droop can be calculated as follows:

$$\text{Frequency (Hz) droop: } (100)[(Hz_{NL} - Hz_{FL}) / Hz_{FL}]$$

$$\text{Voltage (V) droop: } (100)[(V_{NL} - V_{FL}) / V_{FL}]$$

NL = no load

FL = full load

Figure 2 illustrates the impact of incorrect no load voltage settings. Generator 1 always carries more load than Generator 2. Generator 2 experiences reverse kVAR at no load.

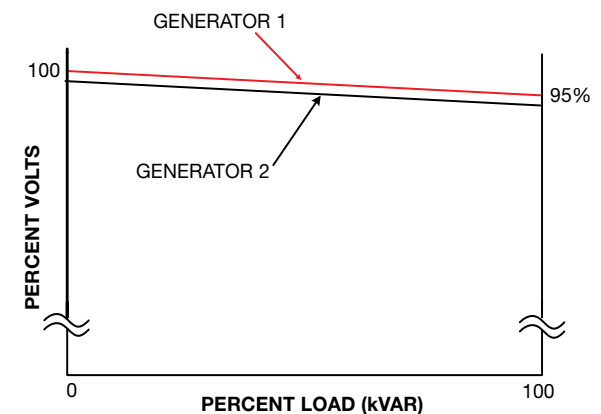


Figure 2 - Generators droop at the same rate but start at dissimilar voltages. Generator 1 always carries more load than Generator 2. At no load Generator 2 experiences reverse kVAR.

Figure 3 shows the impact of dissimilar droop settings.

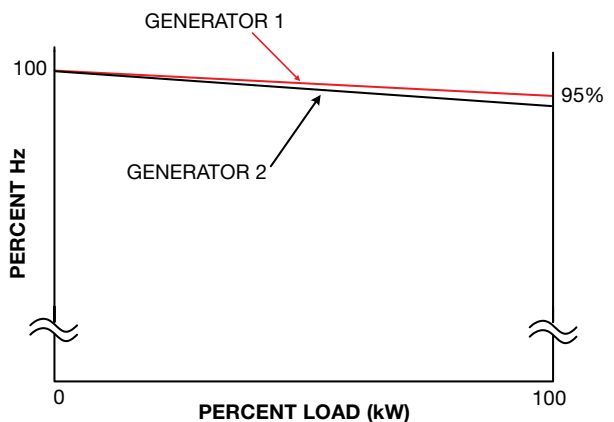


Figure 3 - Generators start at same no load frequency but have different droop rates. Generator 1 always carries more load than Generator 2.

Note that systems always require both kW and kVAR load sharing, but they do not both need to be the same type of system. One can be isochronous and the other can be droop. VAR load sharing via droop is often termed “reactive droop compensation.”

The major advantage of using droop in paralleling is that it allows dissimilar machines to be paralleled without concern for their load sharing interface. The voltage variations that occur due to droop operation are not significant in isolated bus systems, but the frequency variations that occur due to droop operation can be significant, especially in emergency/standby systems where the load can vary considerably over time. Common droop selections for frequency and voltage can be different and are typically in the range of 3–5% from no load to full load.

Droop governing can generally be used for generator loading control in single generator set-to-utility paralleling systems, because the utility frequency is usually very constant. However, reactive droop is not effective for utility paralleling due to the greatly varying voltage level at any point in a utility distribution system as the load on the system changes. Var/power factor controllers should be used when generators are paralleled to a utility or other “infinite” source.

Cross current compensation

Cross current is a flow of electrical current between generator sets that is caused by dissimilar excitation levels in those sets. Cross current compensation is a

term describing the operation of paralleled generator sets without intentional voltage droop. This is achieved by the insertion of a current transformer (CT), usually on “B” phase of each generator, and interconnecting the CTs together to provide an identical voltage bias to each AVR in the system. The system works best when the voltage regulators are all of the same manufacturer and model. Not all voltage regulators work together in this mode, so the best planning practice is to make sure that all the voltage regulators in a system that uses cross current compensation are identical. This may require changing all the voltage regulators in the system to a new model. Using cross current compensation results in no intentional droop in voltage from no load to full load on the system, so it is considered to be superior to a reactive droop compensation system from a performance perspective.

Isochronous kW and kVAR load sharing

Isochronous load sharing control systems are active control systems that actively calculate the percentage of real and reactive load on a specific generator set, compare those values to the percentage of real and reactive load on the system, and then provides control to the fuel and excitation system of the generator to drive the percentage of load on the generator to the same value as the percentage of load on the system. Load sharing is critical to paralleling compatibility, because the load sharing communication is the only point where generator controls interact with each other

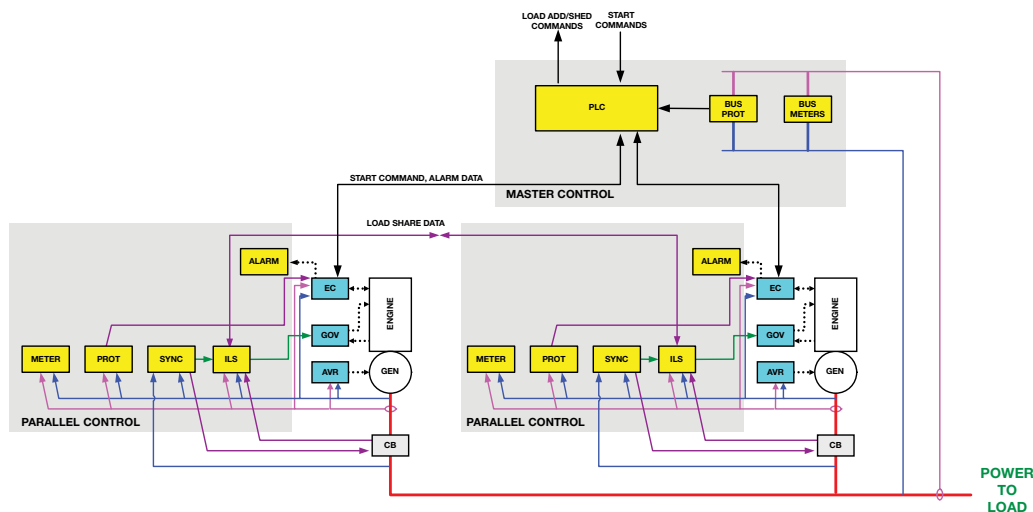


Figure 4 - A functional block diagram of a simple isolated bus paralleling system showing interface of generator sets, paralleling functions and master control system. Note that the only interface between the generator sets is the load sharing signals.

when operating on an isolated bus. Figure 4 shows this interface.

To provide load sharing functions, each generator set in the system must have controls that will calculate the total percentage of kW and kVAR load on the machine, and then have a means to compare that value to that of the system as a whole. Several approaches are available in the marketplace to provide this interface. In general, they can be broken into two large groups:

- Systems that use analog signals for load sharing
- Systems that use digital communication signals for load sharing (such as CAN, RS485 or Ethernet)

Analog control systems often respond faster than digital communication/control systems and can often be made to be compatible between different manufacturers. Cummins manufactures an analog isochronous load sharing interface (ILSI) module that can be used for interfacing Cummins PowerCommand® systems with other load sharing controls that use analog signals.

Digital communication/control systems are different for every supplier, so any system that uses them needs to have load sharing control functions done by the same make and model of equipment. The newest integrated paralleling controls (those that provide all the paralleling functions on a single circuit board) almost all use proprietary digital communication/control signals for load sharing. As a result, as a new supplier approaches an existing generator set with paralleling equipment in place, the typical recommendation will be to replace the existing paralleling controls with new controls all from the same supplier. This has been particularly common as the cost of these single board controllers has dropped dramatically compared with historical control systems for load sharing and other paralleling functions. While this may seem excessive or difficult (in the past it would have been), in fact it may be the most reasonable approach to managing the load sharing interface. The latest digital controllers integrate all the paralleling functions into a single control board, which has a common load sharing interface (speed bias to governor control and voltage bias to the AVR), making the controls easy to interface with nearly any generator set.

At least one supplier offers a load sharing interface module (gateway) for use with digital communication/

control-based load sharing equipment, but a designer will need to clearly identify the responsibility for performance of the system if the gateway is not fully functional, or be prepared for more dramatic system changes if the load sharing gateway performance is not acceptable.

Using different operating modes for load sharing

The availability of single board paralleling controllers for upgrade of existing equipment has led to a whole range of possible variations in how generator sets can be added to existing systems, and how paralleling control upgrades can be accomplished.

When trying to interface dissimilar load sharing equipment from different suppliers, it is also possible to configure the system so that some of the generator sets in the system operate at a base load level, and others operate in a load share state. The base load machines operate at a constant load, while the generators operating in isochronous load sharing mode will “float” with the balance of the available load. Occasionally the total load on the base-load machines will be manipulated by a PLC. This system is viable when there are not sudden large load changes in a system.

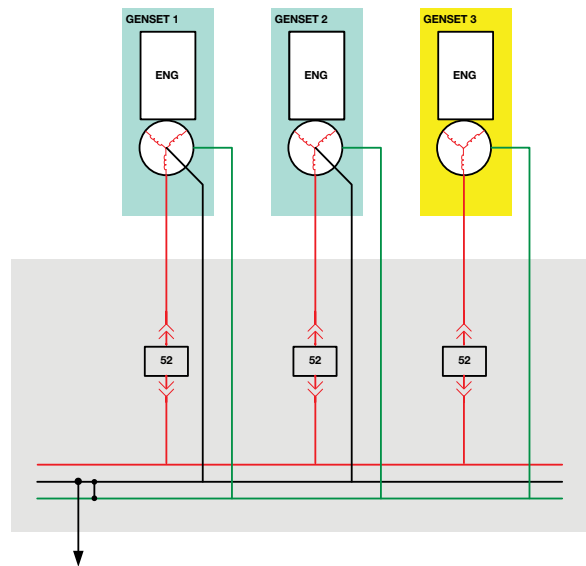


Figure 5 - System with two identical generator sets and one dissimilar, showing neutral not connected.

Figure 5 illustrates a situation where three 1000 kW generators are connected together in a system, with one machine dissimilar to the other two.

In this case, since the system is an isolated bus arrangement, assume that the generators share reactive load via droop. The kW load sharing could be accomplished as follows.

Generator 3 (yellow machine) is set up so that it can't be the first to start, and it is not used unless at least one of the other generators is on the bus. It operates in droop for kW load sharing. With the other two machines operating at 60 Hz, Generator 3 is set to operate at a slightly lower speed that is sufficient to cause it to operate with a 500 kW load when in parallel with either or both of the other machines.

With Generator 1 and Generator 2 running and carrying system load, Generator 3 is synchronized and closed to the bus, and it assumes its preset load level. It operates at a fixed load until it is disconnected from the bus (Figure 6).

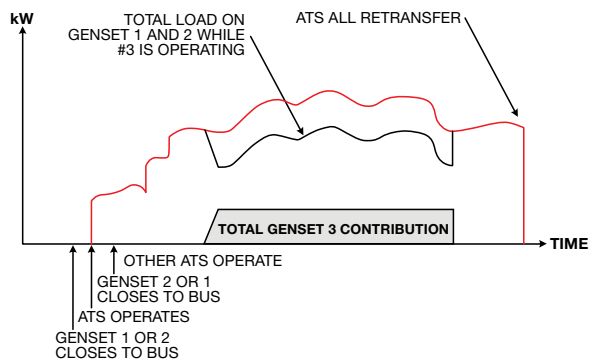


Figure 6

In a similar fashion, load govern (grid-parallel) loading controls can sometimes be used to cause some of the machines in a system to operate at a fixed kW and/or kVAR load level, while the balance of the system operates isochronously and shares load proportionally. In cases where this is used and the load level on the system varies significantly, a PLC or other device may be used to vary the load level on the machine(s) in load govern state to prevent over- or under-loading of the machines operating in load share mode.



About the author

Gary Olson graduated from Iowa State University with a BS in mechanical engineering in 1977, and graduated from the College of St. Thomas with an MBA in 1982. He has been employed by Cummins Power Generation for more than 25 years in various engineering and management roles. His current responsibilities

include research relating to on-site power applications, technical product support for on-site power system equipment, and contributing to codes and standards groups. He also manages an engineering group dedicated to the design and development of next-generation power systems.

Conclusions and recommendations

Generators operating in parallel must have a means to share applied system loads without being either overloaded or underloaded.

Two common means of load sharing on an isolated bus are droop and isochronous load sharing. Droop is simple to implement and inherently allows for dissimilar control systems to be used, but has the disadvantage of more variation in frequency and voltage levels. Frequency variation is likely to be more problematic.

Isochronous load sharing systems cause all gensets in a system to operate at the same percentage of load, but they generally require that all the gensets have a common load sharing control system in order to share load properly. All the load sharing controls should be of the same type and from the same manufacturer.

Other means to share load are possible, but they require a thorough understanding and control of system loads to prevent misoperation of the system and potential damage to generator sets due to reverse kW or kVAR conditions that might occur or that are due to overloads. Consideration should be given to the capabilities of the vendor undertaking the paralleling of dissimilar machines, to be certain that when the project is completed, successful operation is achieved.



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